BLATT 11 – HOCHDRUCKLUFTANLAGE (EINBAUGLEICH GESEHEN)
Plan 11: High Pressure Air System (as installed)

a **BORDVENTIL DRUCKLUFT-ÜBERNAHME**
Hull valve, outboard air lines

a1 **BORDVENTIL: HOCHDRUCK-LUFTGRUPPE — z. B. 6**
Hull valve: high pressure air bank . . . for example, 6

b **HOCHDRUCK-LUFTGRUPPE — z. B. 1**
Manifold valves, high pressure air bank . . . for example, 1

b1 **TORPEDO-HOCHDRUCK-LUFTGRUPPE**
Torpedo-high pressure-air bank

b2 **NIEDERDRUCK-LUFTGRUPPE TYFON**
Low pressure-air bank to "Tyfon" whistles

c **ANSCHLUSS — z. B. REGELVENTIL NIEDERDRUCK-LUFTVERTEILER**
Manifold connection . . . for example, regulating valve-low pressure air distributor

c1 **FÜLLANSCHLUSS — z. B. HOCHDRUCK-LUFTFLASCHEN-GRUPPE 1**
Charging or filling connection . . . for example, high pressure air bank 1

c2 **HOCHDRUCK-LUFTANSCHLUSS — z. B. DRUCKÖLFLASCHE SEHROHRE**
High pressure air connection . . . for example, oil-pressure tank for hydraulic periscope control

c3 **DRUCKLUFT-ÜBERNAHMEANSCHLUSS**
Compressed air-filling or charging connection

c4 **HOCHDRUCK-LUFTFÜLLANSCHLUSS TORPEDO**
High pressure-air charging or filling connection for torpedoes

d **STRANG HOCHDRUCK-LUFTGRUPPE — z. B. 5**
Stop valves, high pressure-air banks . . . for example, 5

e **FÜLLEN HOCHDRUCK-LUFTVERTEILER**
High pressure air to manifold

f **HAUPTANBLASEVENTIL TAUCHZELLE**
Master blow valve for blowing ballast tanks

f1 **ERSATZANBLASEVENTIL TAUCHZELLE**
Auxiliary blow valve for blowing ballast tanks

f2 **ANBLASEVENTIL — z. B. TAUCHZELLE 3, STEUERBORD**
Main ballast blowing valve . . . for example, main ballast tank 3, starboard

g **HAUPTAUSDRÜCKVENTIL — z. B. UNTERTRIEBSZELLE**
Main blowing valve . . . for example, to negative buoyancy tank

g1 **AUSDRÜCKVENTIL — z. B. REGELZELLE STEUERBORD 1**
Blowing valves . . . for example, regulating tank 1, starboard

h **REGELVENTIL NIEDERDRUCK-LUFTVERTEILER**
Master valve to low pressure air distributor

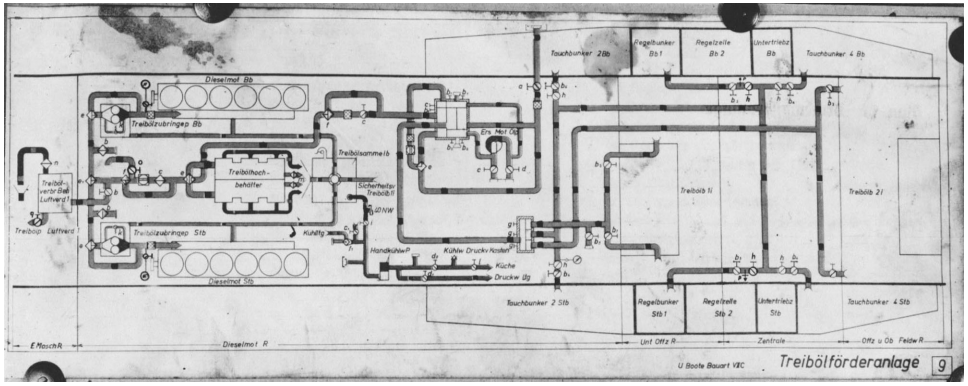
h1 **DRUCKLUFT-REGELVENTIL ANKERSPILLMOTOR**
Compressed air-regulating valve for anchor capstan motor

i **DRUCKMINDERVENTIL — z. B. 205 > 30 ATÜ ANLASSLUFTFLASCHEN**
Pressure reducing valve . . . for example, 205 > 30 atmospheres in starting air flasks

k **FAHRVENTIL ANKERSPILLMOTOR**
Operating valve for anchor capstan motor

l **AUSTRITT — z. B. LUFTVERDICHTER 1**
Discharge valve . . . for example, from air compressor 1

m **ENTWÄSSERN** - Drain valves



BLATT 10 – DRUCKWASSERANLAGE
Plan 10: Fuel Oil Compensating System (Circulating Water under Pressure)

a **BORDVENTIL DRUCKWASSERLEITUNG**
Hull valve, compensating water line

b **DRUCKWASSERWÄHLER — z. B. TAUCHBUNKER 2, STEUERBORD**
Pressure water selector . . . for example, main ballast and reserve fuel oil tank 2, starboard

b1 **KORROSIONSSCHUTZÖL-WÄHLER: HANDPUMPE KÜHLWASSER**
Anti-corrosion oil-selector: hand pump for cooling water

c **DRUCKWASSERANSCHLUSS — z. B. TREIBÖLBUNKER 2 INNEN**
Pressure water connection . . . for example, internal fuel oil storage tank 2

c1 **LENZANSCHLUSS: TREIBÖLBUNKER INNEN**
Bilge connection: fuel oil storage tank, inboard

d **DRUCKWASSERSCHALTER**
Pressure water control/selector cock

e **ENTLEEREN DRUCKWASSERLEITUNG**
Drain valve, pressure water line

f **SICHERHEITSVENTIL DRUCKWASSERLEITUNG**
Safety valve, pressure water line

f1 **UNTERDRUCK-SICHERHEITSVENTIL: TREIBÖLBUNKER — z. B. 1 INNEN**
Negative pressure safety valve: fuel oil storage tank . . . for example, 1 inboard

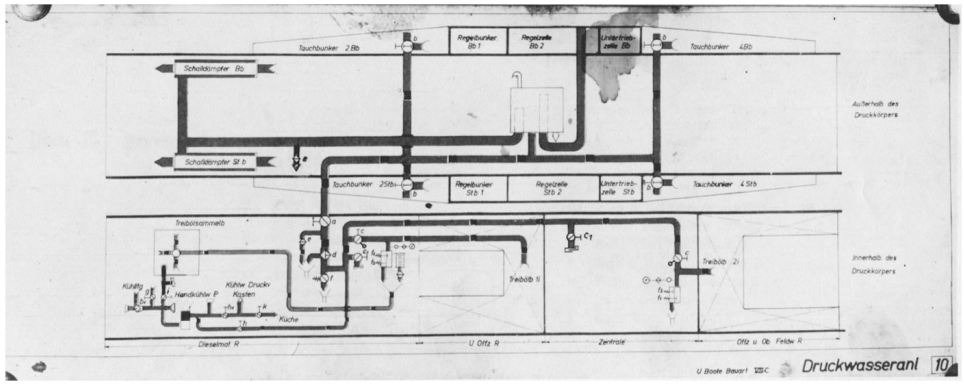
f2 **ÜBERDRUCK-SICHERHEITSVENTIL: TREIBÖLBUNKER — z. B. 2 INNEN**
Excess pressure safety valve: fuel oil storage tank . . . for example, 2 inboard

g **SEEWASSEREINTRITT: HANDPUMPE KÜHLWASSER**
Sea water inlet: hand pump for cooling water

h **DRUCKWASSERAUSTRITT: HANDPUMPE KÜHLWASSER**
Pressure water discharge: hand pump for cooling water

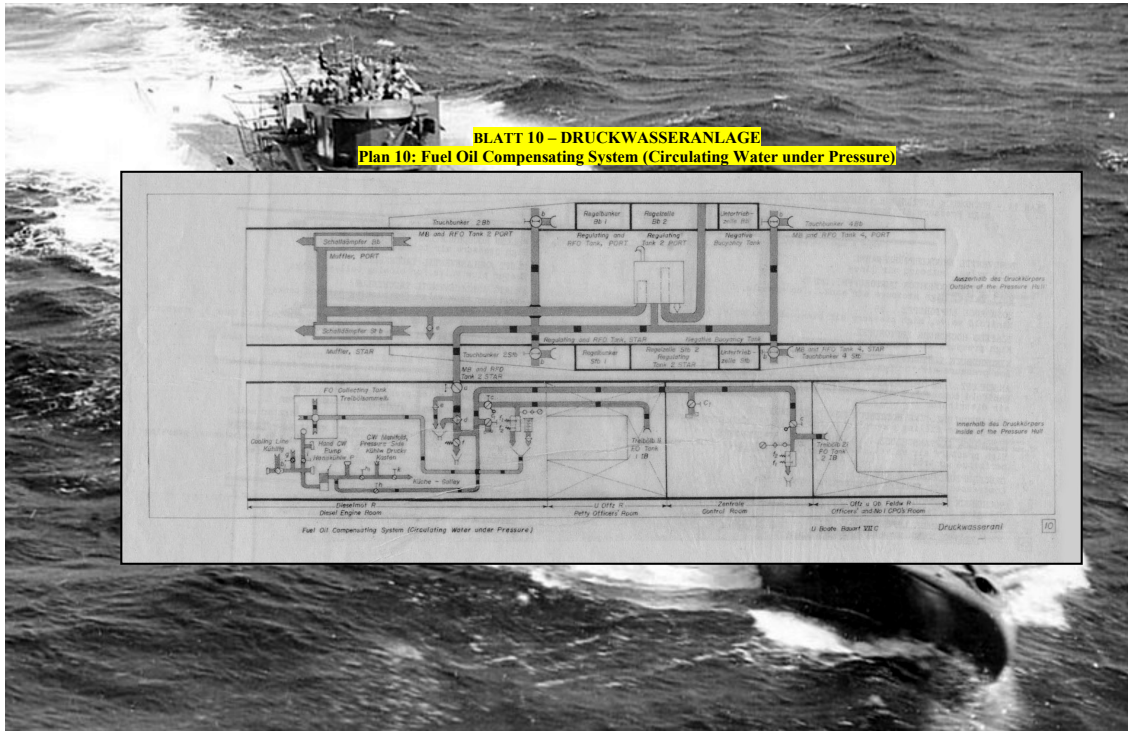
i **LENZEN TREIBÖLSAMMELBEHÄLTER**
Suction (valve for drawing off sediment), fuel oil collecting tank

k **SEEWASSER KÜCHE**
Sea water to galley



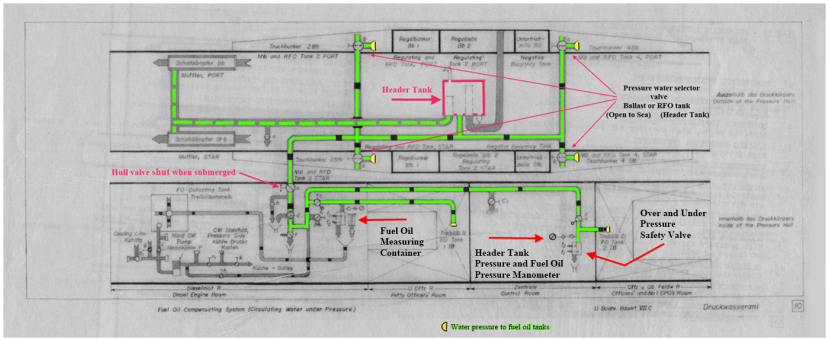
Plan 10 Druckwasseranlage

a	Bordw Druckw Ltg	f1	Unterdr Sicherheitsw Treibölb ... zB 1 i
b	Druckw Wähler ... zB Tauchb 2 Stb	f2	Überdr Sicherheitsw Treibölb ... zB 2 i
b1	Korrosionsschutzölwähler Handdrühlw D	g	Seew Eintr Handdrühlw D
c	Druckw Anschl ... zB Treibölb 2 i	h	Druckw Austr Handdrühlw D
c1	Lenzanschl Treibölb i	h1	Kühlw Austr Handdrühlw D
d	Druckw Schalter	i	Lenzen Treibölsammelbeh
e	Entleeren Druckw Ltg	k	Seew Küche
f	Sicherheitsw Druckw Ltg		



BLATT 10 – DRUCKWASSERANLAGE

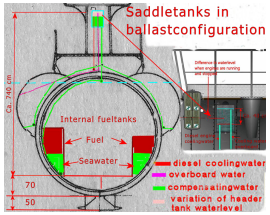
Plan 10: Fuel Oil Compensating System (Circulating Water under Pressure)


Header Tank
Pressure water selector valve
Ballast or RFO tank
(Open to Sea) (Header Tank)
Hull valve shut when submerged
Fuel Oil Measuring Container
Header Tank Pressure and Fuel Oil Pressure Manometer
Over and Under Pressure Safety Valve
Fuel Oil Compensating System (Circulating water under Pressure.)
Water pressure to fuel oil tanks:

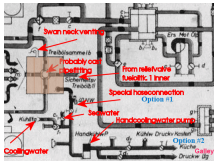
The cooling water from the diesel engines is pumped through the pressure hull to cool the exhaust mufflers. This heated water is directed to the header tank where a portion is stored and some is channeled to the fuel oil tanks or the configurable RFO saddle tanks (FBT 2 and FBT 4), but not RFO Tank No.1. Normally, when you use the compensating water you pressurize the fuel tanks and then you do not have compensating water consumption. The gravity/day tank is divided into two sections; port and starboard and the total capacity is 720 liters. Only the bunker fuel tank selected to supply fuel to the diesel engine day tanks would require compensating water equal to one side of the day tank (360 liters maximum). The average fuel consumption depends upon many factors; the selected speed range in rpm (LF, HF, 2 x HF, GF, 2x GF, and AK), and if one (1) or both diesel engines are running. For example, let's say 200 liters/hour is consumed at GF economy [3/4 speed at 420 rpm using one (1) diesel engine and its e-motor as a generator to power the e-motor on the other drive shaft] and the surface running speed is 6.1 knots. The e-motor driven prop shaft is only maintaining about half the rpm as the diesel engine driven prop shaft. You swap the day tanks every hour and top off the idle tank with 200 liters of fuel. Therefore, the average compensating water consumption is 200 liters/hour. Compared to the total cooling water supplied from one (1) diesel engine which is approximately 2,000 liters/hour, so only about 10% of the cooling water is used for water compensation while economy cruising on one diesel engine and one e-motor on the surface. The amount of water pressure provided to the fuel oil tanks and RFO tanks is the result of the height of the water column form the deck of the winter garden to the level of water in the tanks. The design is really ingenious; as the tank's water level rises the water column becomes shorter resulting in less pressure in the tank (self-regulating). This simplistic design provided enough internal water pressure to keep the fuel at the top of the fuel oil tanks. The header tank's overflow pipe dumps excess water into the sea; the goose neck pipe at the top of the header tank is to provide air pressure equalization in the tank, and the 4th pipe on the right is a hot sea water supply pipe to the galley and the sanitary system.

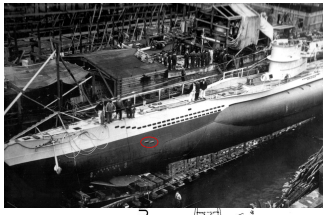
When the U-Boat submerges the header tank system pressure is kept constant, equal to a liquid column height from the compensating pipes sea inlet in the external fuel tanks and the top of the header tank water level, regardless of the diving depth of the U-Boat. The internal fuel tanks are shut to the external compensating system by the hull valves (a) on Plan 10.

80



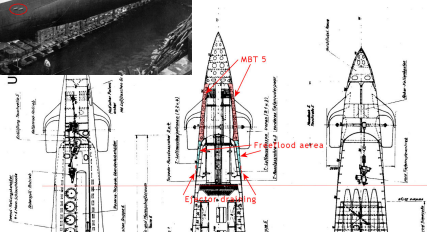
In the image to the left, the water supply pipe from the engines ends up some 20 cm above the bottom of the header tank to prevent a complete draining when the engines are stopped. When the engines are running the water is filling the header tank until the overboard pipe approximately 10 cm from the top of the tank. The water goes overboard normally keeping the tank topped up to 10 cm from the top cover. Furthermore, the bottoms of the internal fuel tanks are not going all the way to the lowest part of the pressure hull (see my sketch). This means that when surfaced an estimated pressure of the internal fuel tanks open to the system might vary between 740 and 700 cm of water column height or corresponding to 0.74 and 0.70 kg/cm^2 or 10.5 and 9.95 lbs./sq. inch. The diagram to the right shows 2 options in **BLUE** as to how the fuel oil collecting tank in **TAN** is emptied. Option #1 uses a special hose connection and an external suction pump to collect the contents. Option #2 uses the internal hand pump to suction the tank contents which is collected at the galley into buckets. The latter is NOT the preferred method.





Surface running issue with free flood bow area

The oval port shaped blisters are open at the back end **(Left photo circled in RED)** and have a very simple function; they help drain water from inside the free flooded structure area between MBT 5 and the pressure hull. Water in this location was a big problem at sea when the U-Boat was cruising on the surface. Water entered the flood gates above the torpedo tube outer doors and damned up in back of MBT 5 in the frontal area between the pressure hull and the outer bow casing. This extra weight lowered the bow and exacerbated the problem; so, more power was required to drive the U-Boat on the surface. This problem occurred first on the Type I and later on Type VII A. At first, the Germans made several changes in the flooding hole design. In some pictures of U35 you can see that they have cut additional flood holes just at the position of the "Blisters" on later U-Boats.

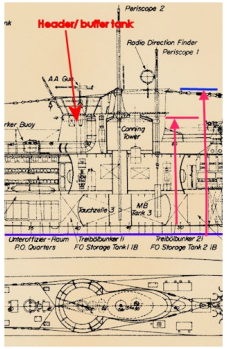


The fix was to drain some water from the bow flood gate flowing above the forward pressure hull area and back toward the limber holes in the hull side casing.

"In order to try to explain the reason for the position of the ejector drain (and flood gate), I made the image (left) showing the horizontal cross section of a VII C at about the level between the upper and lower torpedo tubes. The **PINK** color outlines MBT 5 and the **BLUE** color outlines the difficult and narrow void space between the casing and the pressure hull. When the U-Boat speeds ahead on the surface and the blisters are below the waterline; there will be a suction effect in the "blister nostril" draining the difficult void space."

- Tore Berg-Nielsen

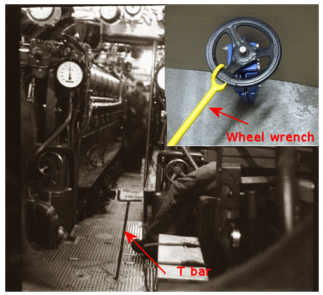
89



To the left is a section from a drawing of a Type VII C U-Boat design with an early bridge configuration. The location of the header tank **(Far left RED arrow pointing down)** is located under the winter garden deck. Some of the older U-Boat crewmen referred to it as the buffer tank.

Another thing to notice is the tallest arrow that goes from the bottom of the keel to the top of the bridge wind deflector; that height is 9.397 meters. The keel is .55 meters tall; if we subtract the height of the keel and about 2 meters to get down to the water height in the header/buffer tank, then the height of the water column going to the two internal tanks is about 6.8 meters or about 22.34 feet. A water column at that height has the potential of providing a substantial amount of pressure and volume dependent upon the pipe diameter.

The pressure selector valves located at the top of the FBT 2 and FBT 4 tanks are used to configure the tanks as a standard ballast tank (shut) or an RFO tank (open). In the RFO selection, the tank is connected to the header tank water system. However, in the ballast tank selection, this valve is shut and isolated. The ballast tanks can now utilize the open Kingston valves to allow water to enter the tanks, and the common duct vent valves to allow the air to escape and be displaced by water in the ballast tanks.



The Tank Conversion during heavy seas

This conversion is an outside job for a crewman to change the U-Boat to the water ballast tank configuration. The two (2) photos below show the tools required for this change-over job; a "T" tool (lower left photo) and a hand-wheel wrench-claw (lower right photo). In the left photo, the crewman is holding a "T" tool with a socket tip to fit over the gate valve drive shaft. Then the external gate valve could be changed to the water ballast tank configuration. However, the FBT 2 residual gate valves may have the hand-wheel and may prove to be difficult to turn since these valves are exposed to the elements and salt water, so additional force may be required to get the job done. Then this situation will call for the use of a hand-wheel wrench-claw which clamps over the hand-wheel outer rim and straddles a wheel spoke. Now, the crewman may apply extra turning torque to change the gate valves position from shut to open. The crewman was doing his duty under terrible weather conditions; he was wearing a safety tether line to avoid getting washed overboard. The upper right photo shows different types of tools used by the crewmen.

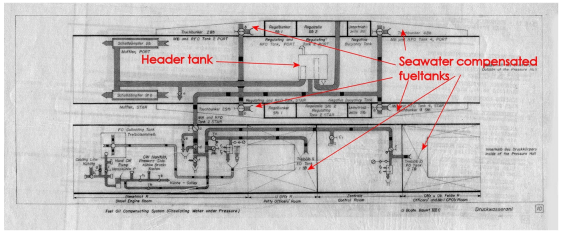
Safety relief valves and a measuring device on the internal fuel oil tanks

On each internal fuel oil tank there is a set of safety valves and they monitor the fuel oil header compensation pressure going to the internal fuel tanks. One is preset to blow on an over pressure condition and the other is preset to blow on a under pressure condition. During a dive, if the hull valve (a) on Plan 10 had a leak, or was not shut, then the internal fuel oil tanks 1 and 2 are exposed to external sea water pressure. However, safety valve (f1) in the engine room and the control room protects the internal fuel oil tanks from over pressure. The under-pressure safety relief valves (f2) are paired with a manometer on the line for monitoring the absolute internal pressure of the fuel oil tanks. These safety valves protect the internal fuel oil tanks from both over and under pressure. An under-pressure problem would happen if valve (a) were not opened, and auxiliary lubrication oil pump (suction) was used to draw fuel oil from an internal fuel oil tank in a special situation which will be covered extensively later.

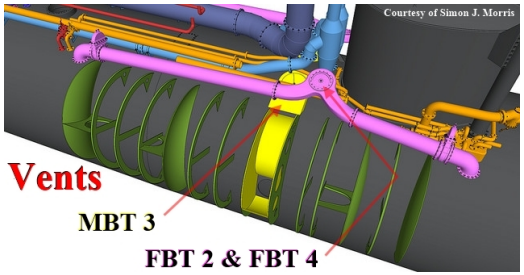
The compensating water column pressure head for the internal fuel oil tanks 1 IB (inbound) and 2 IB is about the same. However, the water column pressure head for the external fuel oil tanks FBT 2, R 1, and FBT 4 would be considerably less because of the shorter distance between the header tank water level and the bottom of the saddle tanks. Below, I have listed a logical order for the fuel oil usage and conversion, but conditions and circumstances in a war patrol may dictate something entirely different:

1. R 1 - for better/easier ballast control when diving or at periscope depth
2. FBT 2 and FBT 4 - converted to the ballast configuration, for better fuel oil economy (less seawater resistance from a pressure hull riding higher)
3. Internal fuel Oil Tanks - not of much concern because the used fuel oil is replaced with compensating water which is permanent for the war patrol; and the U-Boat's horizontal balance is not disturbed.

"However, the way the Germans used the VIICs - I don't think they had so many options. Before leaving for a war patrol they had to store up as much fuel oil as possible. As previously stated, we Norwegians very seldom used the saddle tanks for fuel oil storage as our strategy was mostly coastal defense and having access to fueling stations all along the coast." - Tore



Saddle Tank Construction (MBT 3 Venting Shaft through R - 2) Yellow

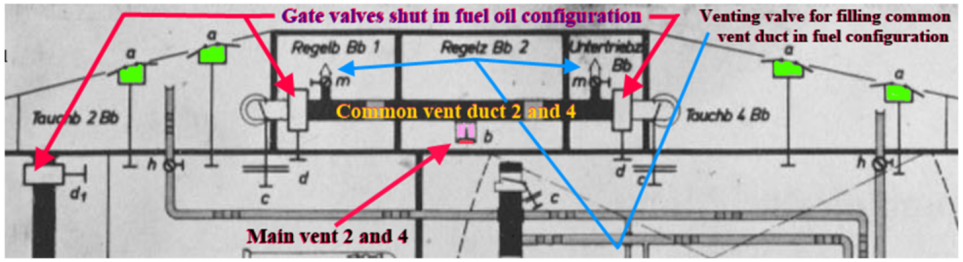


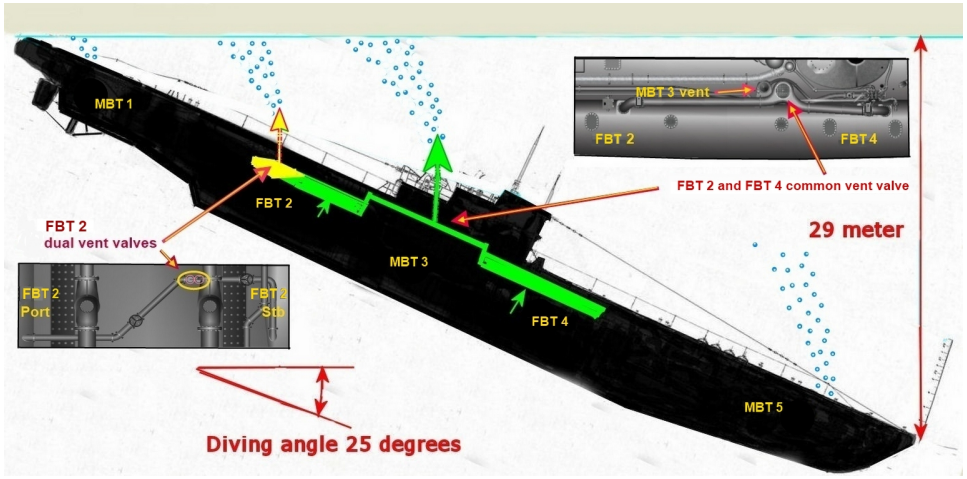
The photo to the left is a good view of an internal gate valve located in the diesel room which is operated from inside the pressure hull. This particular gate valve is the port forward engine room bulkhead gate valve for the U-Boat ventilation system. Notice the heavy construction of the gate valve; a heavy casting which has a hand-wheel gear drive mechanism that drives a sliding plate up into a seat and securely shuts off the attached pipe.

Gate valves shut in the fuel oil configuration (reference Plan 16)

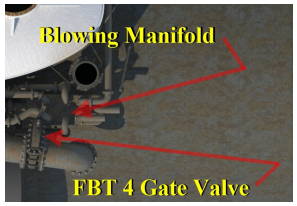
The diagram below is indicating the various gate valves involved in the ballast/fuel oil configuration of the saddle tanks. As a matter of interest, I made a quick calculation of the weight compensation for the difference between the saddle tanks filled with fuel oil (87% the weight of sea water) versus the saddle tanks filled with compensating sea water. With all 4 saddle tanks filled with compensating sea water the weight increase is about 6.5 tons which then had to be taken from the regulating tanks to balance the U-Boat's weight. In the case of not being water compensating tanks, the empty saddle tanks weight loss would be about 43 tons of fuel which would require an equal weight of sea water to be pumped into the regulating tanks to balance the U-Boat's weight. With a total regulating tanks capacity of only 24.6 tons, this would be an impossible task. If you do the same exercise for the internal fuel oil tanks, the total weight increase by compensating sea water filled tanks would be about 9.2 tons and with the saddle tanks increased weight of about 6.5 tons. The total weight gain is about 15.7 tons and still possible to compensate with the regulating tanks' capacity of 24.6 tons. However, without sea water compensating tanks the overall loss of weight would be about 61.5 tons for the empty internal fuel tanks and about 43 tons for the empty saddle tanks; the U-Boat is now about 104.5 tons lighter which must be compensated.

This of course was a play with figures with no realistic use, it's just an example of one of the advantages of water compensating. A second advantage is a reduction of the free surface area effect which may upset the trim. At the beginning of a war patrol, the U-Boats took on full provisions; FBT 2 and FBT 4 were converted to the RFO configuration to take on additional fuel oil. This increase in weight resulted in the waterline being about 9 inches higher on the U-Boat (she was setting lower in the water because of the additional weight).

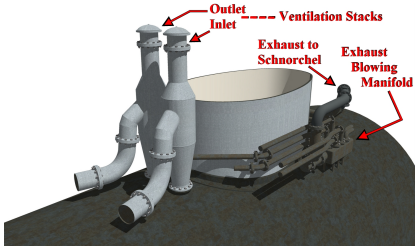

Gate valves shut in fuel oil configuration
Venting valve for filling common vent duct in fuel configuration
Regelb Bb 1
Regelz Bb 2
Untertriebz Bb
Tauchb 2 Bb
Common vent duct 2 and 4
Tauchb 4 Bb
Main vent 2 and 4



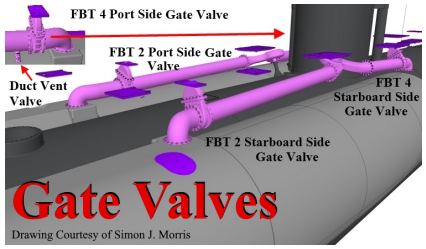
The venting system for the saddle tanks has a special arrangement because the tanks are stretched over a long area of the U-Boat's pressure hull. As the tanks have a common main vent approximately mid-ships, this created a problem particularly when diving at a steep down angle as air will be trapped in the aftermost part of saddle tank 2 port and starboard side (see the above sketch). To overcome this problem a small crossover residual vent pipe having dual vent valves for the aft part of these tanks was installed externally. The vents may be operated from either the control room or the engine room. Like the common main vent pipe for the saddle tanks, the residual vent pipe has individual gate valves which are shut in the fuel oil storage configuration. These FBT 2 gate valves in the main vent pipe and are operated from under the deck casing outside the pressure hull. In the above drawing, the FBT 2 residual vent cross-over pipe has gate valves with hand-wheels which may be removed for operational procedure conformity in all Type VII U-Boats.



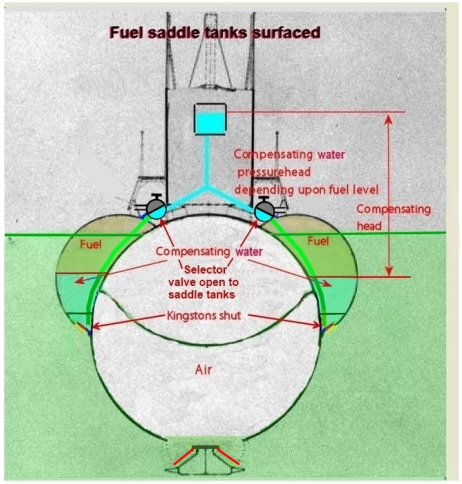
The 3D drawings by Simon J. Morris shows the placement of the exhaust manifold (right drawing) and the valve stems which extend through the pressure hull and into the upper control room starboard side; the exhaust pipe extends to the Schnorchel mast, and the inlet and outlet ventilation stacks are located below the bridge winter garden which are open (mushroom tops raised) while cursing on the surface. Plan 16 (page 82) creates some confusion… The drawing is a bit misleading as some valves like the emergency shut-off valves (c) are drawn correctly having the valve spindle through the pressure hull indicated by a double line crossing the spindle. The gate valve spindles (d) not crossed by a double line indicating to be operated outside the pressure hull e.g. from the casing deck. This is correct, but the gate valves spindles are drawn inside the pressure hull - very confusing! (Upper left drawing) - FBT 4's gate valve is located on the starboard common vent ducts; the gate valves were operated by the crewmen using a "T" tool through a wooden access cover on early U-Boats. (Lower left drawing) U-826 was commissioned on 11 May 1944 and access to the port and starboard FBT 2 and FBT 4 gate valves was through metal covers attached to the wooden deck. Also, the common duct vent valve located near the port FBT 4 gate valve is shown (left upper insert).

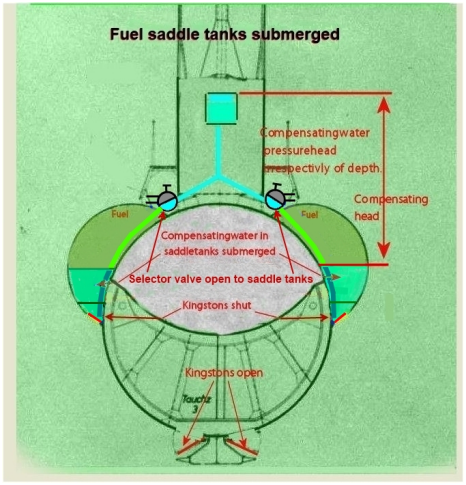


In the RFO configuration; the port and starboard vent valves for FBT 2 and FBT 4 were open, the four (4) duct vent valves were open (2 on each common duct), and the port and starboard gate valves for FBT 2 and FBT4 were shut. The open valves assure that both common vent ducts are flooded during a dive while the saddle/ballast tanks are in the RFO configuration and thereby eliminating any possibility of an air trap and permitted drainage of the common vent ducts when cruising on the surface.


FBT 4 Port Side Gate Valve
FBT 2 Port Side Gate Valve
Duct Vent Valve
FBT 4 Starboard Side Gate Valve
FBT 2 Starboard Side Gate Valve
Gate Valves
Drawing Courtesy of Simon J. Morris

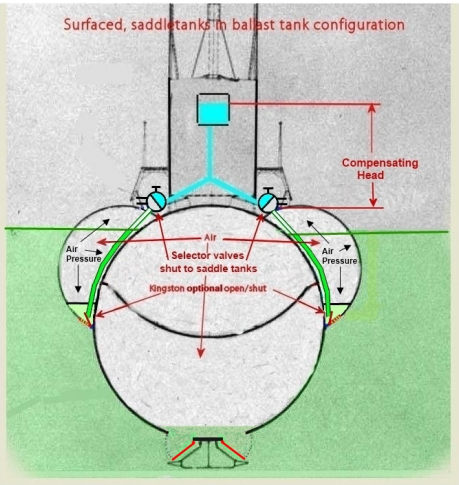
(Right photo) – This is a rare photo that shows the FBT 2 starboard gate valve's wooden cover **(circled in RED)** on an early Type VII U-Boat.

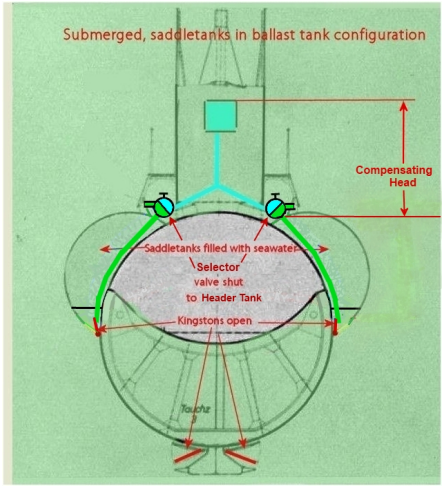




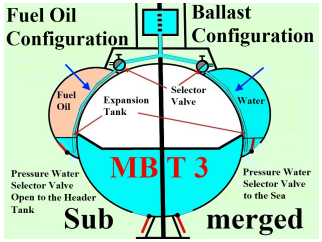
Basically, the system works in the same manner for the internal as the external water compensated tanks. There are several reasons for using water compensation:

1. The compensation of weight loss due to the fuel consumption although the seawater has a higher specific gravity, the weight compensating being plus or minus is less.
2. The free surface effect is reduced which is important particularly to a U-Boat/submarine.
3. It provides a simple way of transferring the fuel in the system.




Submerged, saddletanks in ballast tank configuration
Compensating Head
Saddletanks filled with seawater
Selector valve shut to Header Tank
Kingstons open

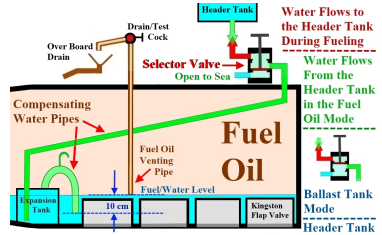
The use of the saddle ballast tanks 2 and 4, port and starboard, as fuel oil tanks require special precautions. The main venting system has to be blocked and secured shut. This is done by shutting the gate valves in the vent duct between the tanks. The vent duct between the gate valves and the main vent has a drain/vent valve which has to be open. The gate valves and the drain/vent valves located outside on the common vent duct are operated from under the casing deck. When diving the main vents for the saddle tanks 2 and 4 are open permanently and not shut while being submerged as ordinary ballast venting so you let the sea water fill the vent pipe to the gate valve. Therefore, the open vent/drain valve and the vent duct is compensated (flooded) and pressure equalized. **Note*** The header tank water pressure selector valves for FBT 2 and FBT 4 port and starboard side never had hand-wheels (the configuration was changed via a "T" tool through a hole in the wooden deck). The hand-wheels were just drawn-in to indicate these were a changeable valve configuration.



During depot fueling (lower drawing), the external fuel supply pressure forces the compensating water out of the saddle tanks (flooder prior to fueling); through the compensating water pipe outlet, the expansion tank, the main compensating water pipe, the selector valve, and up to the header tank where the water overflows to the sea. Close to the end of the fueling procedure, the engine room personnel are always checking the compensating water outlet flow from the test cock arrangement for signs of fuel oil. Once the test cock shows fuel oil, then fueling is immediately stopped for that tank. Now, there is a possibility of fuel oil being trapped in the compensating water system after fueling; fuel oil may remain at the top of the inverted "U" pipe (the goose-neck tube is to vent the trapped fuel oil from the compensating water pipe), or at the very top of the expansion tank. The compensating water pipe extends from the top of the expansion tank and down towards the bottom of the saddle tank. The fuel oil venting pipe is 10 cm above the compensating water outlet pipe end. This difference provides time to stop fueling, and the expansion tank and the saddle tank bottom water takes almost 1.5% of the saddle tank volume as a buffer to prevent fuel oil contamination of the compensating water system. After fueling has been completed and the fuel lines are disconnected from the saddle tanks, the engine room personnel may open the test/drain cock and allow the header tank water pressure to flush the trapped fuel oil in the lines and the expansion tank.

When the U-Boat is submerged in the water ballast configuration, the selector valve connects the compensating water pipe in the saddle tank to the sea and shuts off the compensating water from the header tank at the selector valve (see the drawing insert). The expansion tank could be damaged during a HP air blow with excessive water pressure. However, the connection between the compensating water pipe and the sea allows the pressurized water to exit to the selector valve's sea port and relieve any stress placed on the expansion tank (reference page 481 to view sunken U-352 and see the saddle tank internals).

This elaborate and complicated system has nothing to do with the environment people, clean water and green earth policies did not exist at the time of WWII and the Type VII C U-Boat, but at all cost this was to prevent an oil slick which might betray the U-Boat's position.



Saddle Tank Kingstons Shut in the Fuel Oil Configuration Mode

The saddle tanks have a HP blowing capability, so the hull valves for blowing are shut and secured to prevent structural damage. This arrangement is necessary because direct blowing of the saddle tanks with both the vent valves and the Kingston's shut will damage the tanks structure. The tanks are built with light weight plating and tested to 15 pounds per square inch of pressure, and the internal support structures were designed to sustain the external force from the sea (compression), and not an internal outward force. The compensating water from the header tank goes to the four (4) double-seated selector valves under the deck casing for FBT 2 and FBT 4, port and starboard sides (see Plan 10 on page 80). The valves have only two positions; either compensating water to the saddle ballast/fuel oil tanks through the small expansion tank (at the bottom of the saddle tank) in the fuel oil configuration, or compensating water is shut-off in the water ballast configuration. The drawing to the left shows the header tank location under the U-Boat's winter garden, and the left water compensating selector valve is in the fuel oil configuration, while the right compensating water selector valve is in the water ballast configuration for a comparison.

When the U-Boat is running on the surface and the saddle tanks are in the fuel oil configuration, the Kingston's are shut and the selector valves direct compensation water to the expansion tank and then on to the compensating water pipe outlet to pressurize the external fuel oil saddle tanks. Once the fuel oil saddle tanks are pressurized, no additional compensating water is needed until fuel oil is transferred to an internal tank (i.e., the diesel room's gravity/day tank).